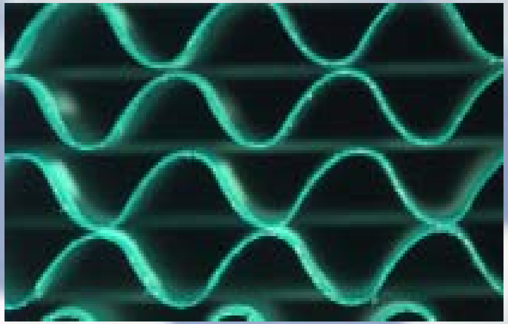
Labs for the 21st Century



Applying 3Å Molecular Sieve Total Energy Recovery Wheels to Laboratory Environments

RMF ENGINEERING, INC · PROFESSIONAL ENGINEERS

JOHNS HOPKINS MEDICINE

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Joint Presentation By:

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- John Fischer
  - Technology Consultant, SEMCO Inc.

Johns Hopkins Ross Research Building:
The Owner's Perspective

Johns Hopkins Ross Research Building:

- 450,000 cfm of combined laboratory/vivarium
- 164 fume hoods, 154 biosafety cabinets and general exhaust through recovery wheels
- Eight SEMCO 3Å molecular sieve coated total energy recovery wheels (14’ diameter)
- 13 years of successful operation

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Initial Risk Assessment Process:

- Head of Health and Safety, Project Engineer, Project Manager and others visited a successful laboratory installation using the wheel technology
- Johns Hopkins installed a 20,000 cfm pilot system in Animal Virology to allow in-house testing by the Health and Safety Office
- Good results led to the acceptance of the technology for the Ross Research Building
- ASHRAE Paper on results by Hopkins Staff (1996)

Ross Building Life Cycle Analysis

- Total recovery wheels offset **1452** tons of chiller capacity and **680** boiler horsepower
- Provided a positive present value cash flow of **$9,100,000** based on 20 year life cycle
- Will provide estimated energy savings in the amount of **$16,600,000** over the 20 year life cycle analysis period

Assumes: inflation at 2.5% and cost of capital of 6%, no taxes

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Maintenance Requirements

- All wheel maintenance is completed in the supply airstream, no need to go in exhaust
- Bearing maintenance, check drive belt, idler and gear motor
- No need to clean media or change labyrinth seals unless damaged
- Media sections replaceable should damage or corrosion occur
- Purge angle adjusted at commissioning
- Initial 5 year parts and labor warranty

Ross Building Maintenance Cost

- No filters in the exhaust air compartment, current pressure loss is within 10% of what it was when new
- Over 13 years maintenance costs amounted to approximately $94,000 in total involving:
  - Annual drive belt replacement
  - Frequency drive upgrade
  - Replaced transfer media in three wheels due to damage
- Maintenance cost less than **1%** of energy savings over first 13 years ($94,000/$9,890,000)

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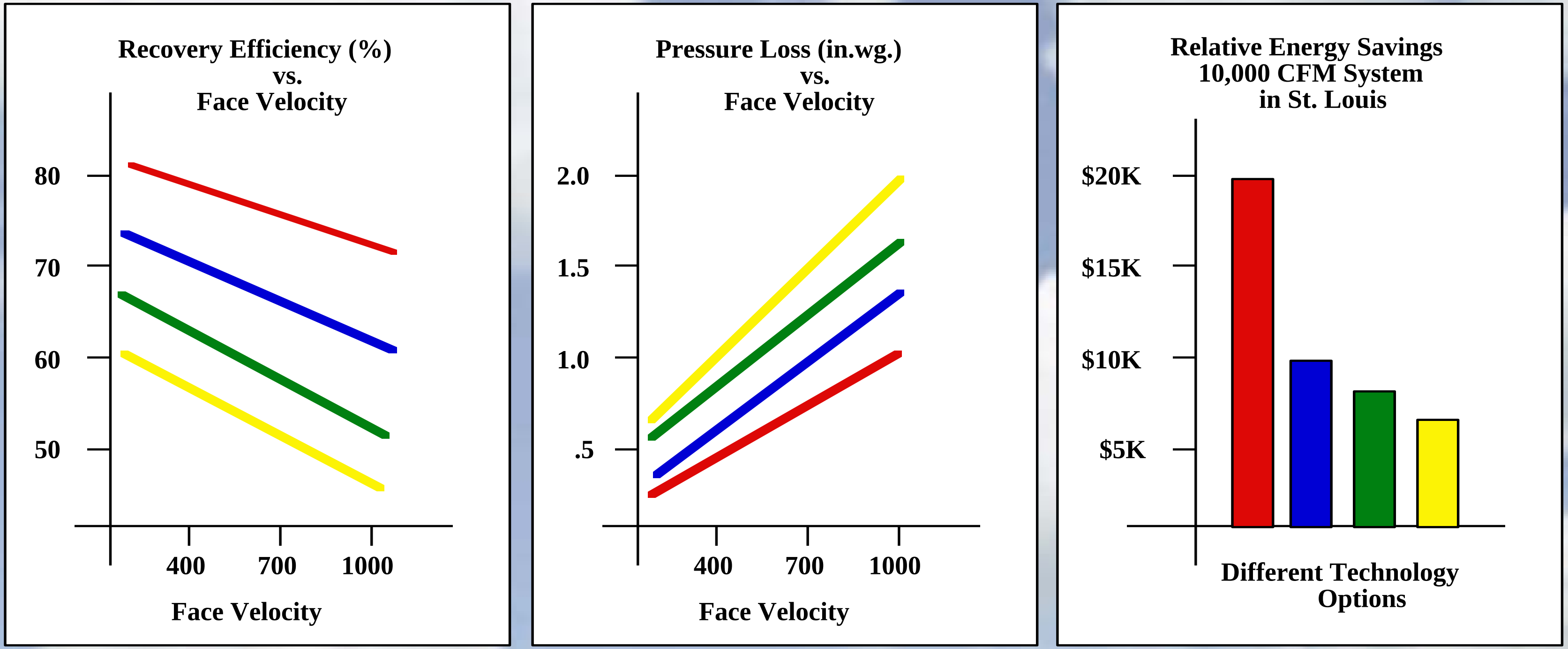
Johns Hopkins Ross Research Building:
Designs Engineer's Perspective

Challenges: Laboratory HVAC Design

- High outdoor quantity of air (often 100%)
- Large cooling/heating plant capacity requirements
- Desire for redundant chiller and boiler capacity
- Corresponding high energy and first cost
- Need for tight temperature & humidity control
- High humidification loads (non-boiler steam)
- Optimize occupant safety within allocated Budget

Comparing Recovery Options



Total Energy Wheel

Plate Exchanger

Heat Pipe

Run Around Coils

Source: ASHRAE and SMACNA Design Guide

Design Considerations

- NFPA 45 and IMC code compliance
- Program functions: Bio-medical, Chemistry, Vivariums?
- Fume hood and BSC density
- Risk assessment with safety officer
- System configuration – penthouse size, height
- Life Cycle Cost Analysis
- Procurement methods

Ross Building: Benefits Recognized

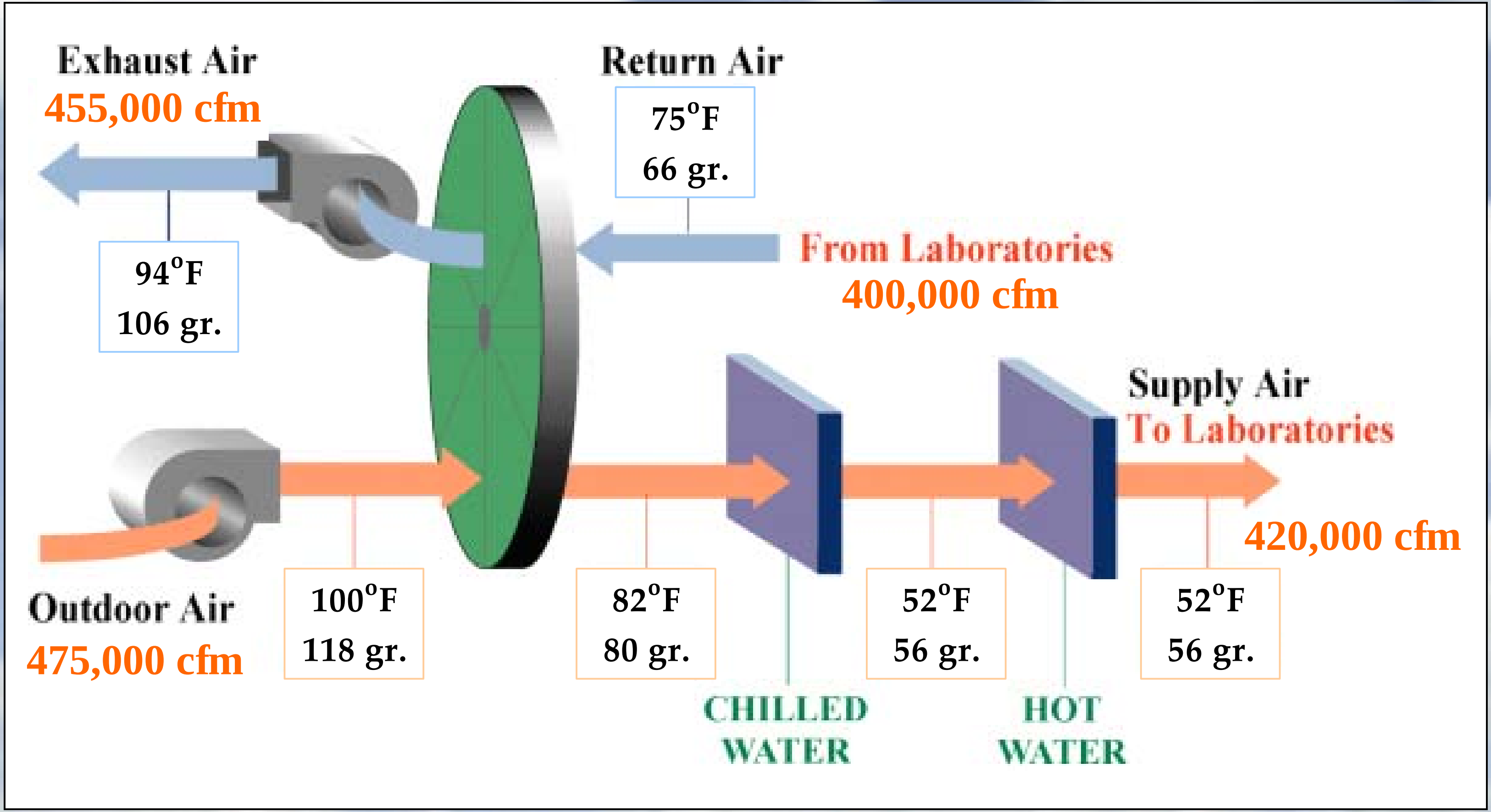
- Economical application of constant volume, 100% outdoor air system to laboratory (preferred by the Head of Health and Safety)
- Significant reduction in first cost, operating cost and life cycle cost. Provided exceptional ROI
- Reduced chiller/boiler capacity requirements allowed for the use of central plant utilities
- Improved humidity control, reduced condensate on cooling coils by 65% and size of steam to steam humidifiers.
- Resolved “freeze-stat” alarms with frozen coils

Johns Hopkins Ross Research Building

Benchmark Capacity:

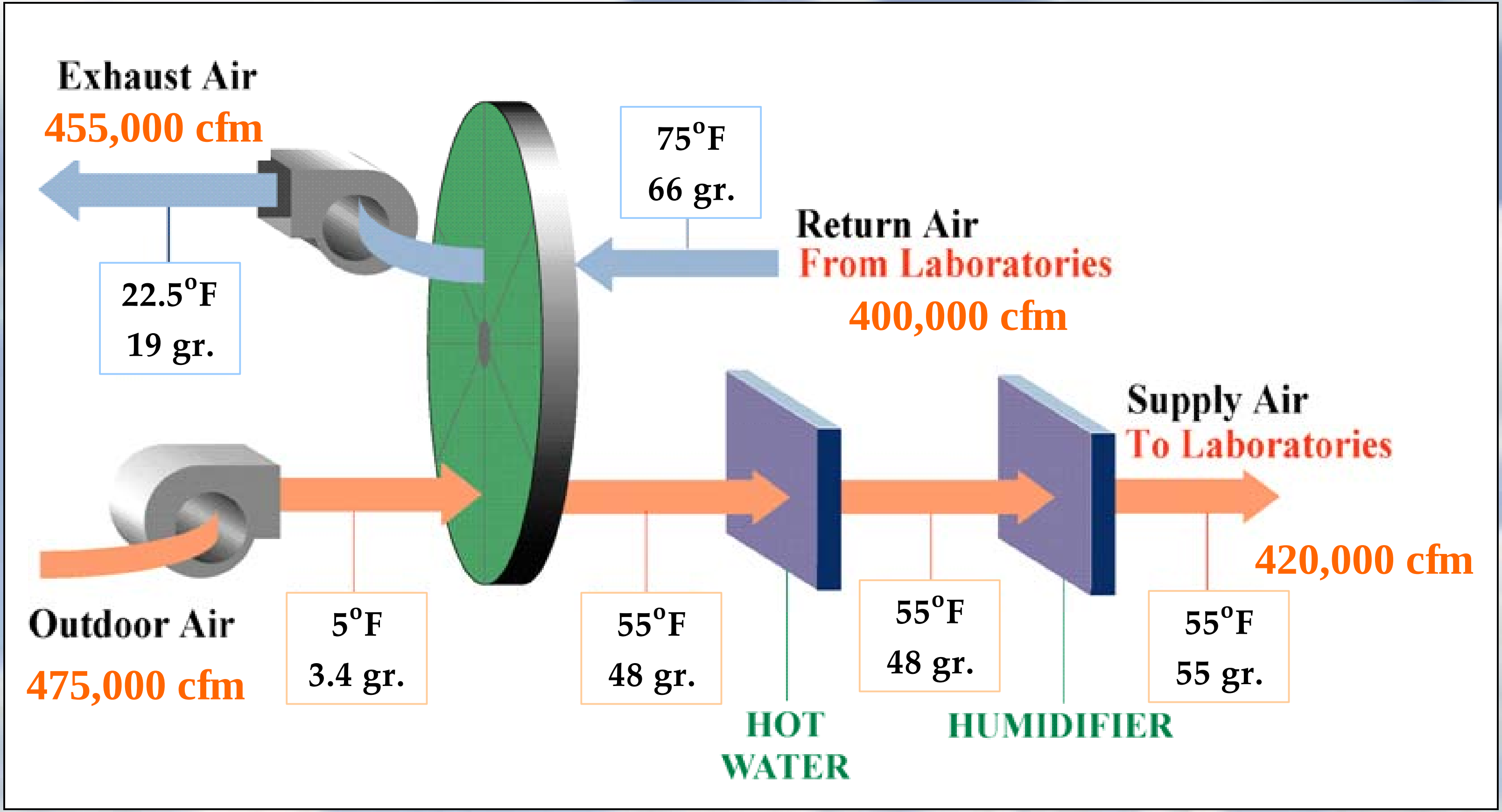
- **335,000 Gross Program Square Feet – 580 Program Modules**
  - **13% Lobby/Core, 43% Lab, 23% Circulation, 14% Office, 7% Vivarium**
- **Fume Hood: 155 Orig.164 Current → 6% Increase**
  BSC's: 88 Orig. 154 Current → 75% Increase
- **450,000 CFM → 1.34 CFM/gsf and 9.5 ACH (8.5' Avg. Clg.)**
  8.5 Watts/gsf
- **3493 Tons Cooling or 96 gsf/Ton wo/HR**
  ↓
  1951 Tons Cooling or 172 gsf/Ton w/HR → 44% Reduction
- **27,850 MBH or 83 BTU/HR/gsf wo/HR**
  ↓
  5,168 MBH or 15 BTU/HR/gsf w/HR → 81% Reduction

Cooling Mode: Ross Building



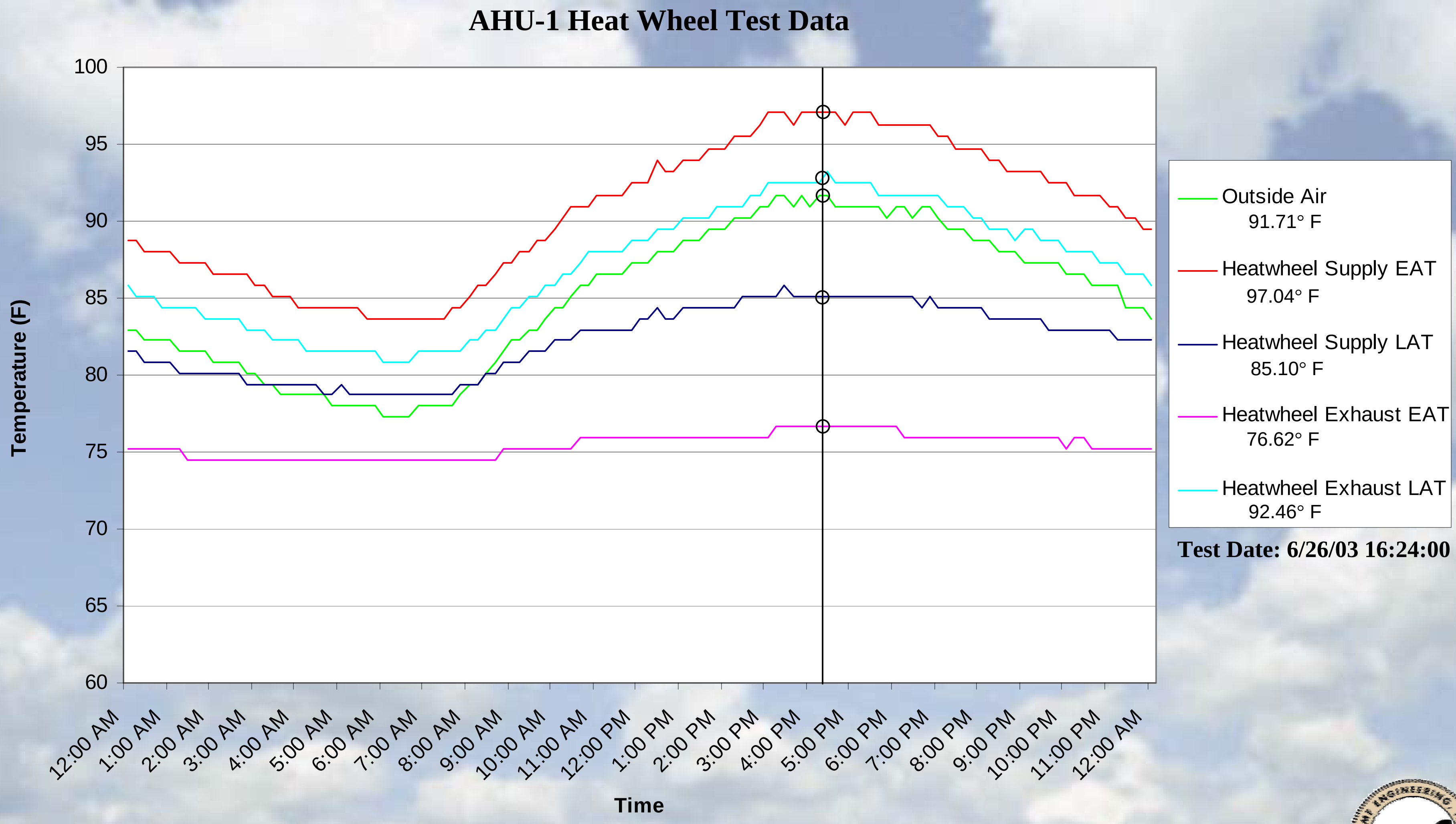
Data reflects initial project design conditions for the cooling mode

Heating Mode: Ross Building

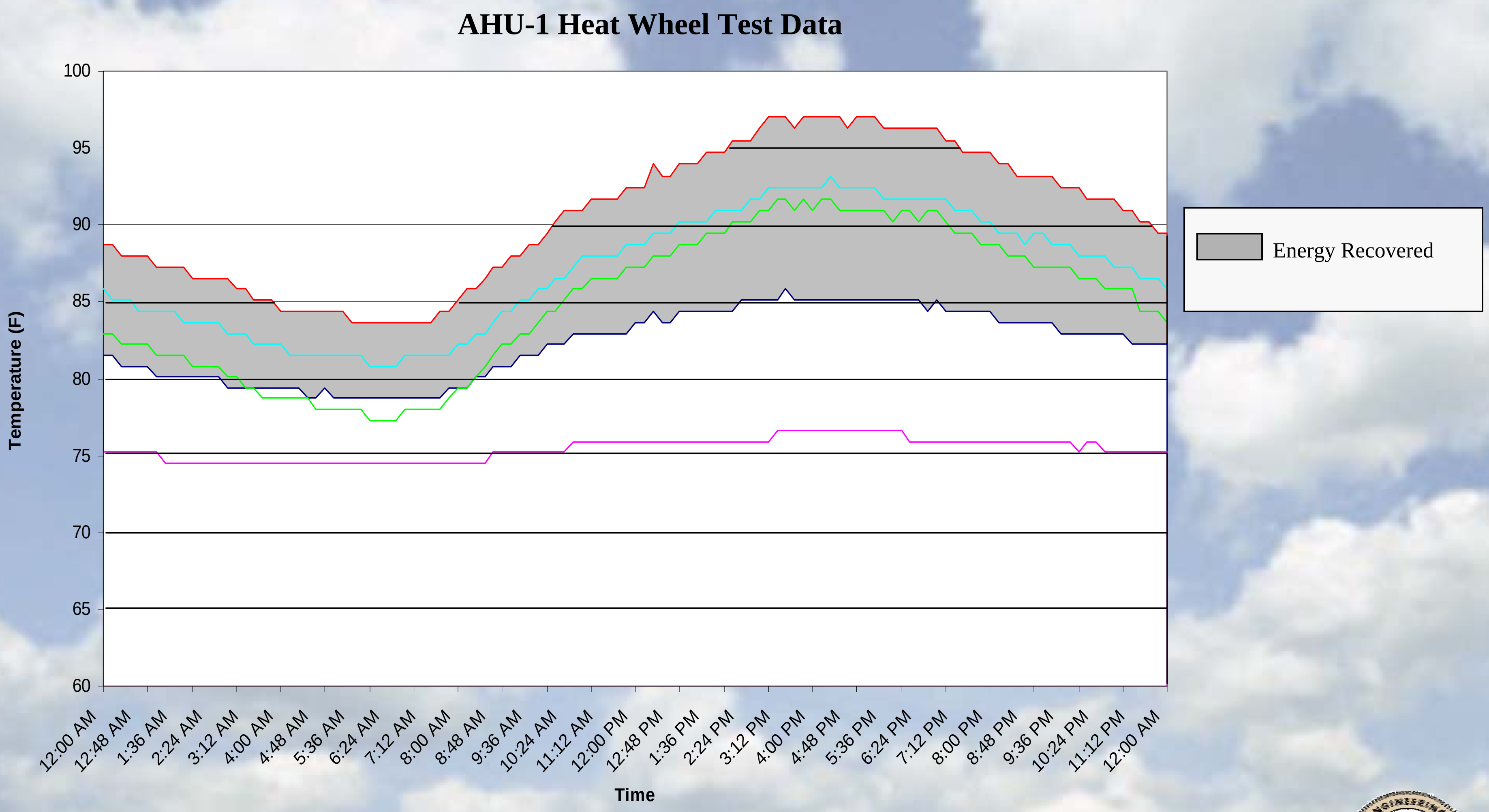


Data reflects initial project design conditions for the heating mode

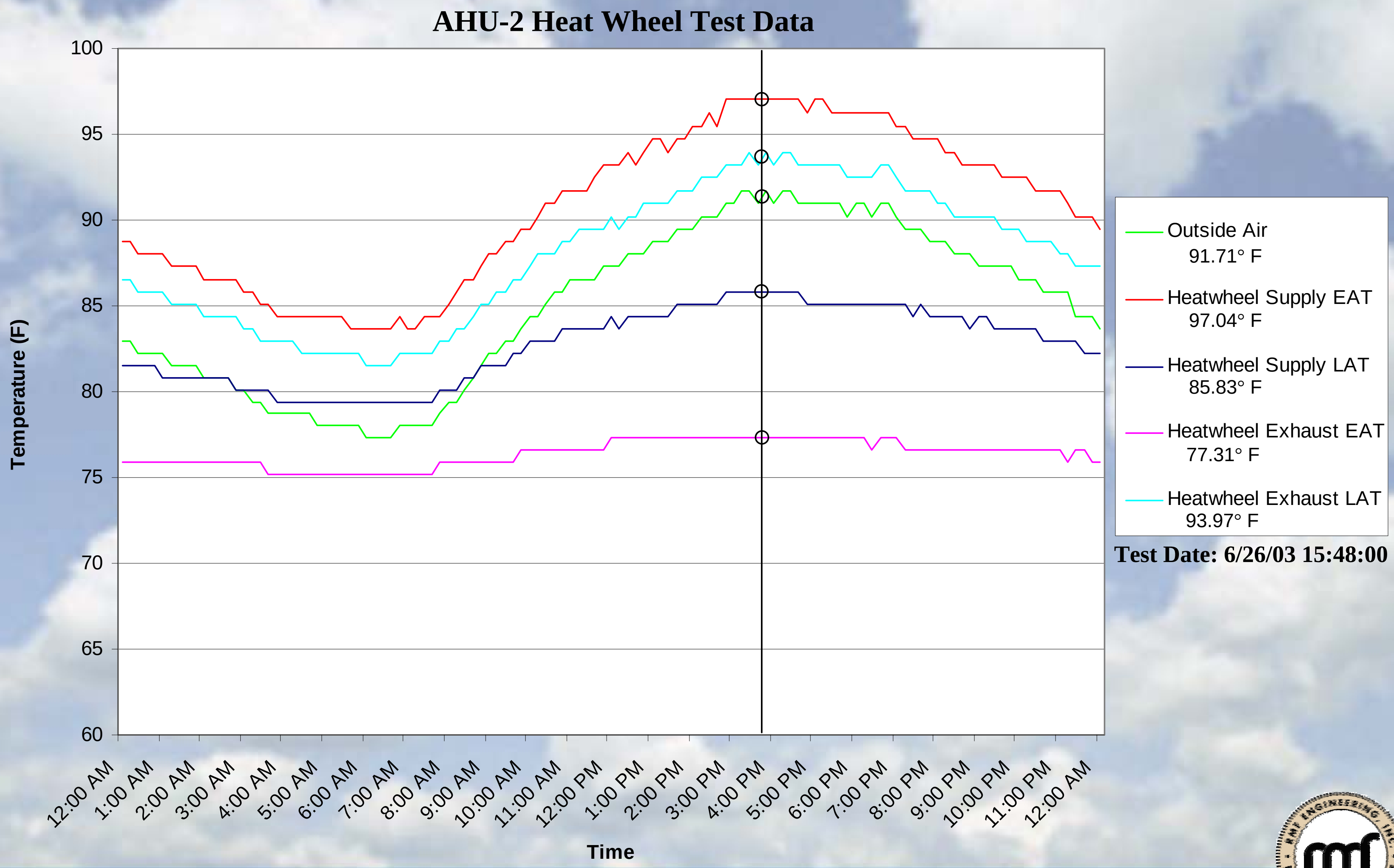
Johns Hopkins Ross Research Building



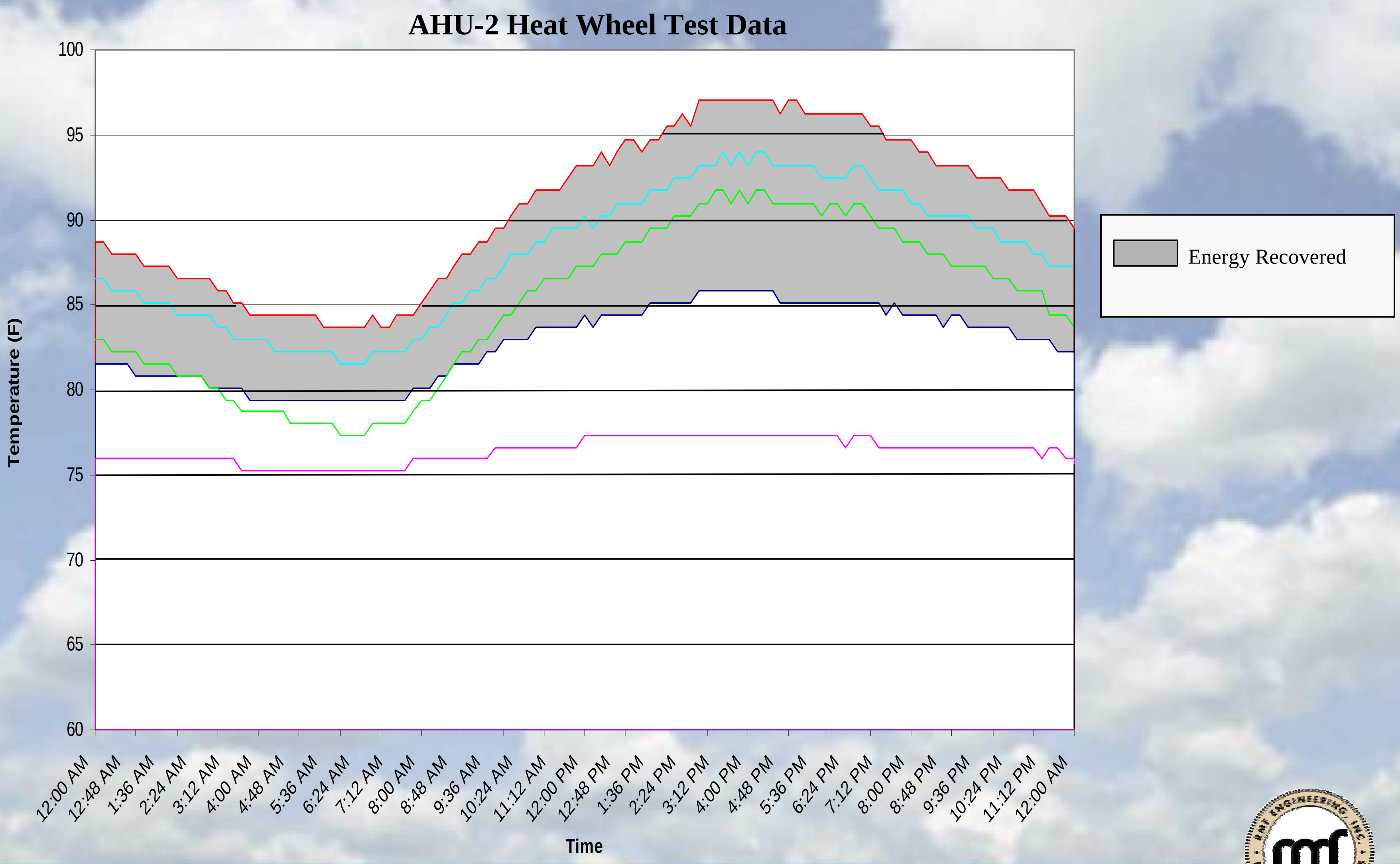
Johns Hopkins Ross Research Building



Johns Hopkins Ross Research Building



Johns Hopkins Ross Research Building



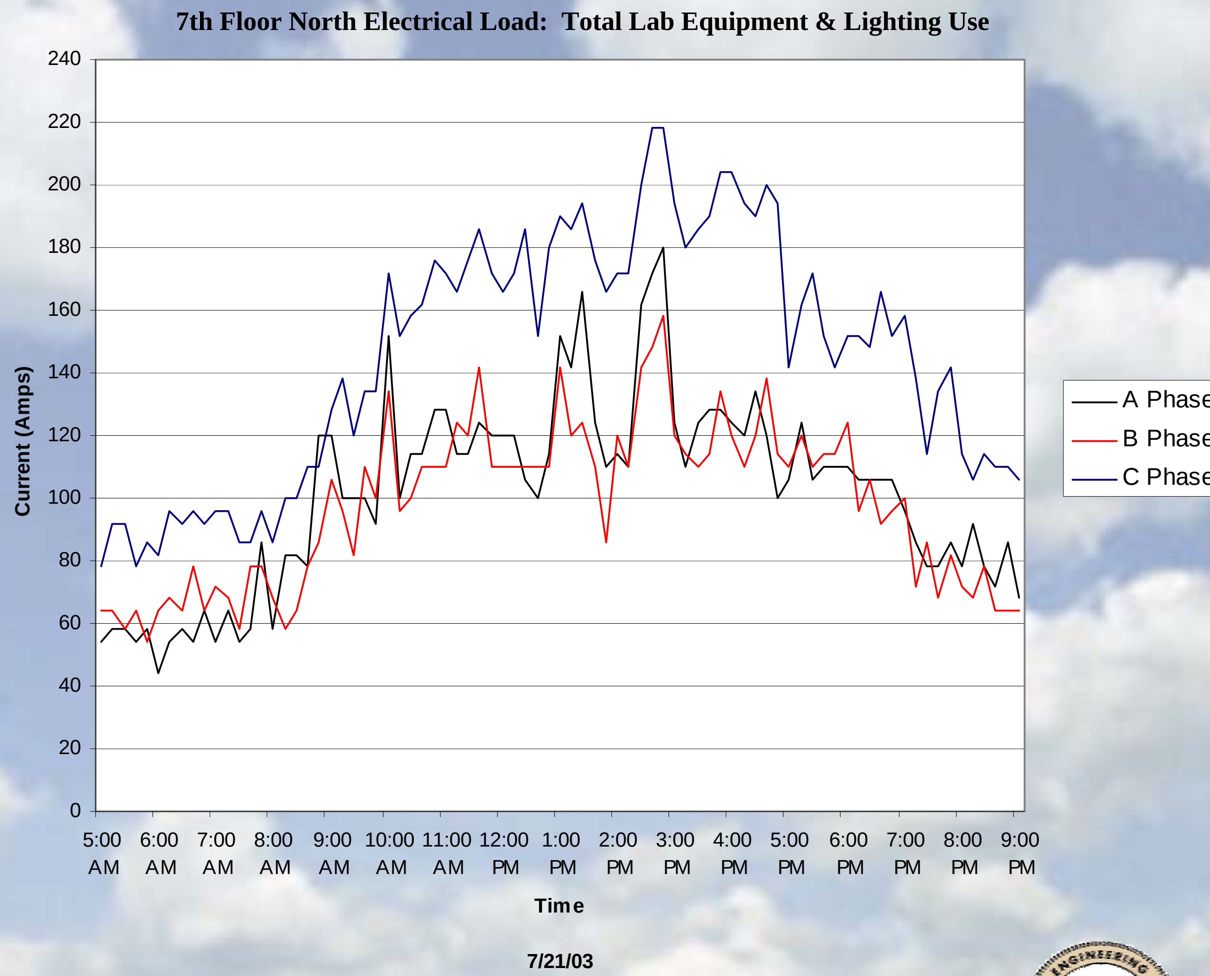
Johns Hopkins Ross Research Building

Benchmark Capacity:

- **7th Floor North – 10,545 gsf**

Lighting and Equipment:
Maximum – 6.0 w/gsf
Average – 3.3 w/gsf
Minimum – 1.8 w/gsf

Equipment: Maximum – 5.0 w/gsf
Average – 2.3 w/gsf
Minimum – 0.6 w/gsf



Johns Hopkins Ross Research Building

Benchmark Capacity:

- **7th Floor North – 10,545 gsf**

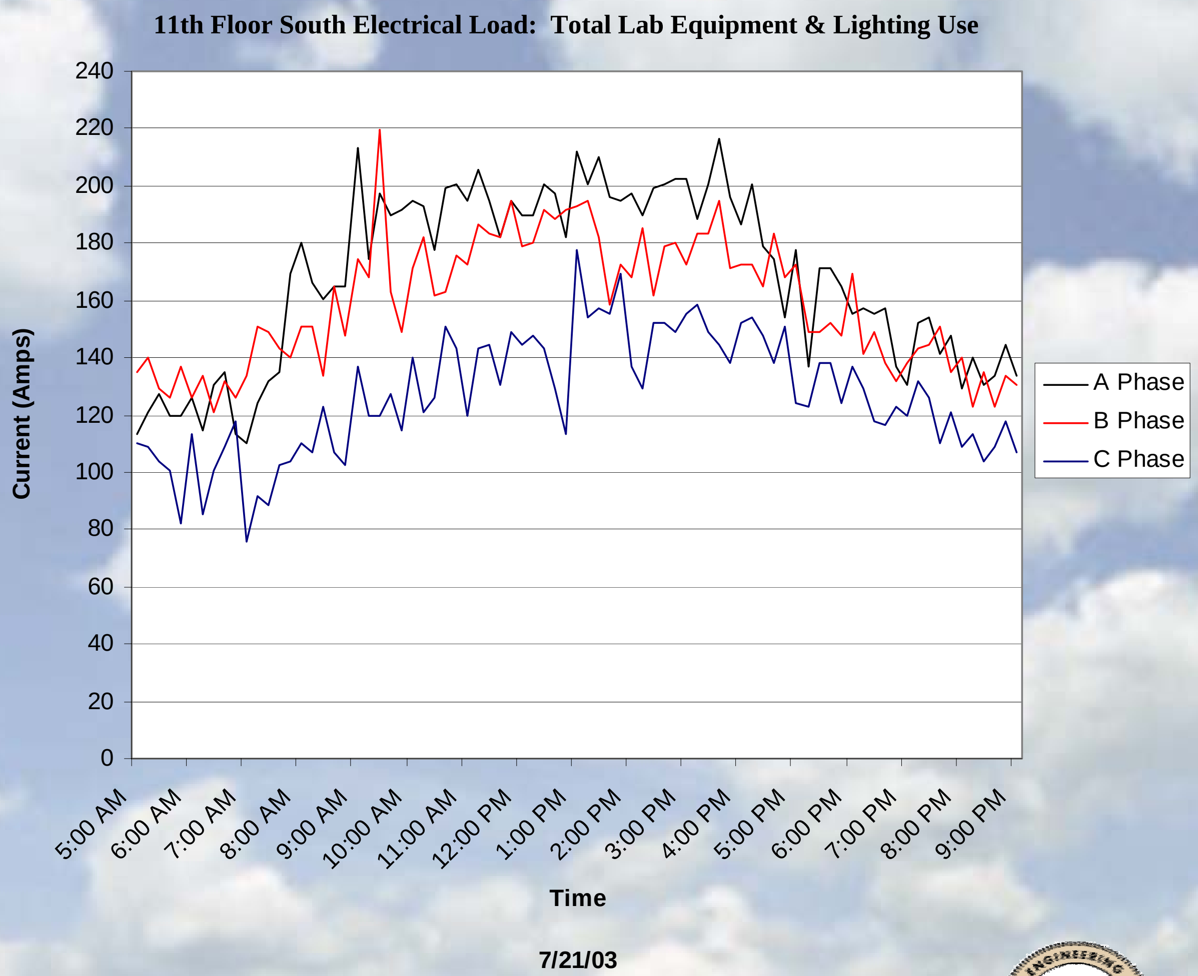
  Lighting and Equipment:
  - Maximum – 6.0 w/gsf
  - Average – 3.3 w/gsf
  - Minimum – 1.8 w/gsf

  Equipment:
  - Maximum – 5.0 w/gsf
  - Average – 2.3 w/gsf
  - Minimum – 0.6 w/gsf

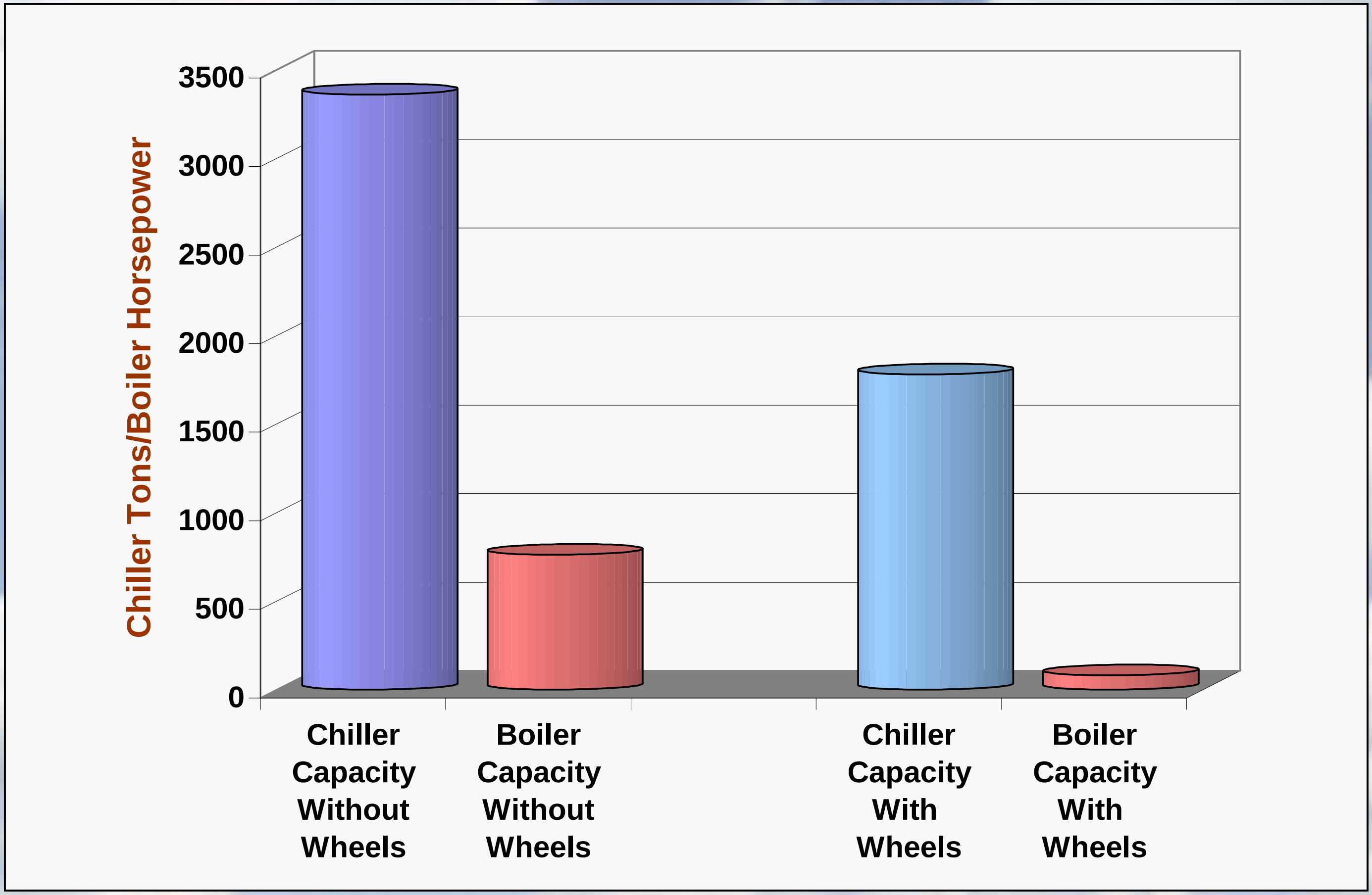
- **11th Floor South – 11,225 gsf**

  Lighting and Equipment:
  - Maximum – 6.2 w/gsf
  - Average – 4.3 w/gsf
  - Minimum – 2.9 w/gsf

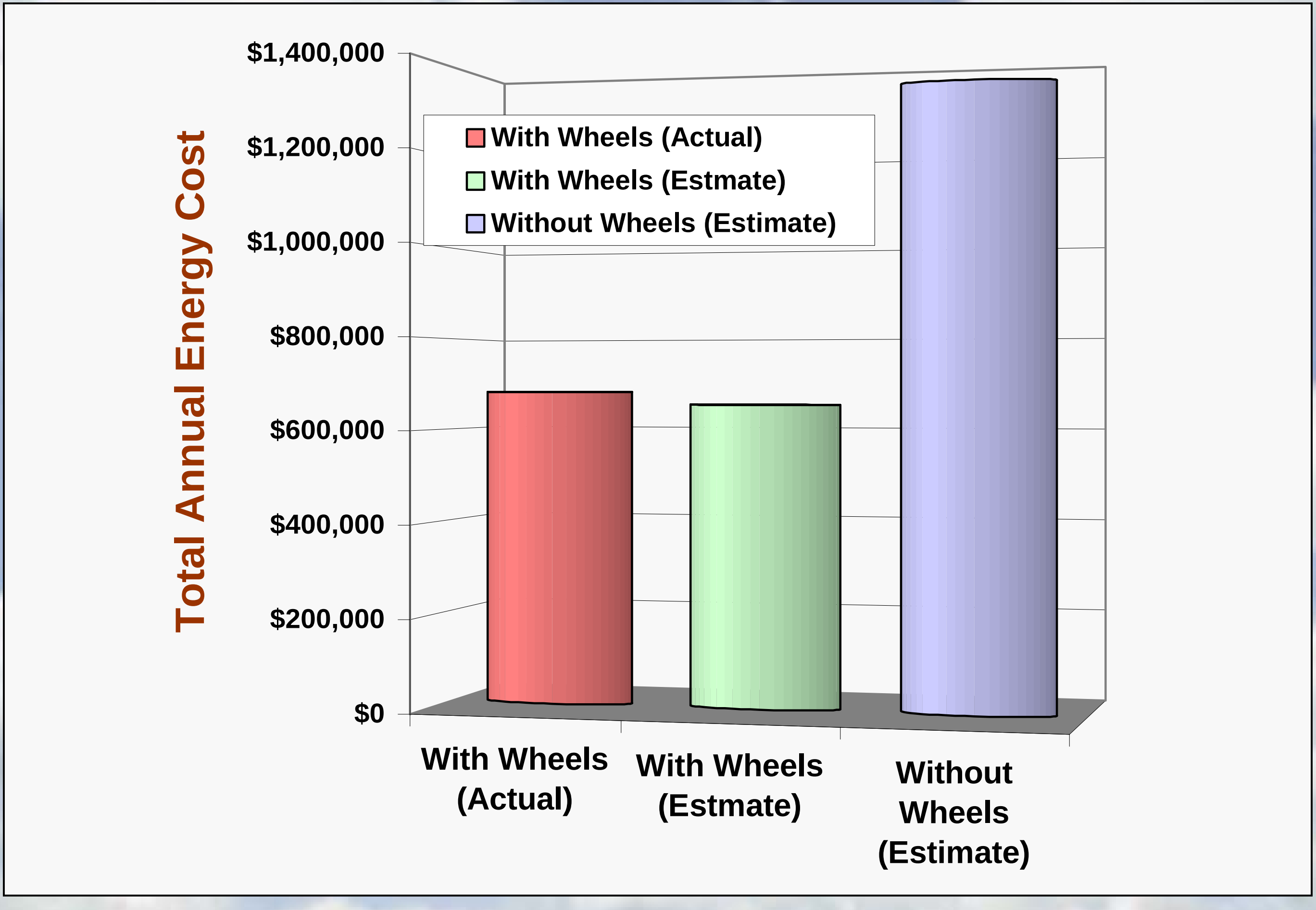
  Equipment:
  - Maximum – 5.3 w/gsf
  - Average – 3.4 w/gsf
  - Minimum – 1.9 w/gsf



Ross Chiller/Boiler Reduction



Ross Energy Cost: Modeling vs. Actual



Analysis based on actual energy cost and wheel performance

Recovery Wheel Economic Summary

Energy Savings	
Annual Chilled water savings	$226,392
Annual Steam savings	$459,440
Total Annual Energy savings	**$685,832**
Chiller/Boiler Plant Savings	
Chiller Capacity required without wheels	3361
Chiller Capacity required with wheels	1780
Tons of Chiller Capacity offset (Tons)	**1581**
Boiler Capacity required without wheels	761
Boiler Capacity required with wheels	82
Boiler Capacity offset (BHP)	**679**

Background for Economic Analysis

Actual Energy Consumed	
Actual Ross Building Energy Consumption (2002)	
Chilled water	$726,767
Steam	$624,741
Baseline (non-AHU) steam consumption	$556,019
Net AHU steam consumption	$68,722
Vivarium Energy Consumption (2002) (37,000 cfm)	
Chilled water	$73,038
Steam	$40,820
Main ERU east and West Energy Consumption (2002) (440,000 cfm)	
Chilled water	$653,729
Steam	$27,902
Total Energy Consumed	$681,631

Background for Economic Analysis

Modeled Energy Consumed (With Wheels)	
Main ERU east and West Energy Consumption (2002) (440,000 cfm)	
Chilled water	$628,344
Steam	$25,976
Total Energy Consumed	**$654,320**

Modeled Energy Consumed (Without Wheels)	
Main ERU east and West Energy Consumption (2002) (440,000 cfm)	
Chilled water	$854,736
Steam	$485,416
Total Energy Consumed	**$1,340,152**

Documented Energy Recovery Performance After 13 Years of Operation

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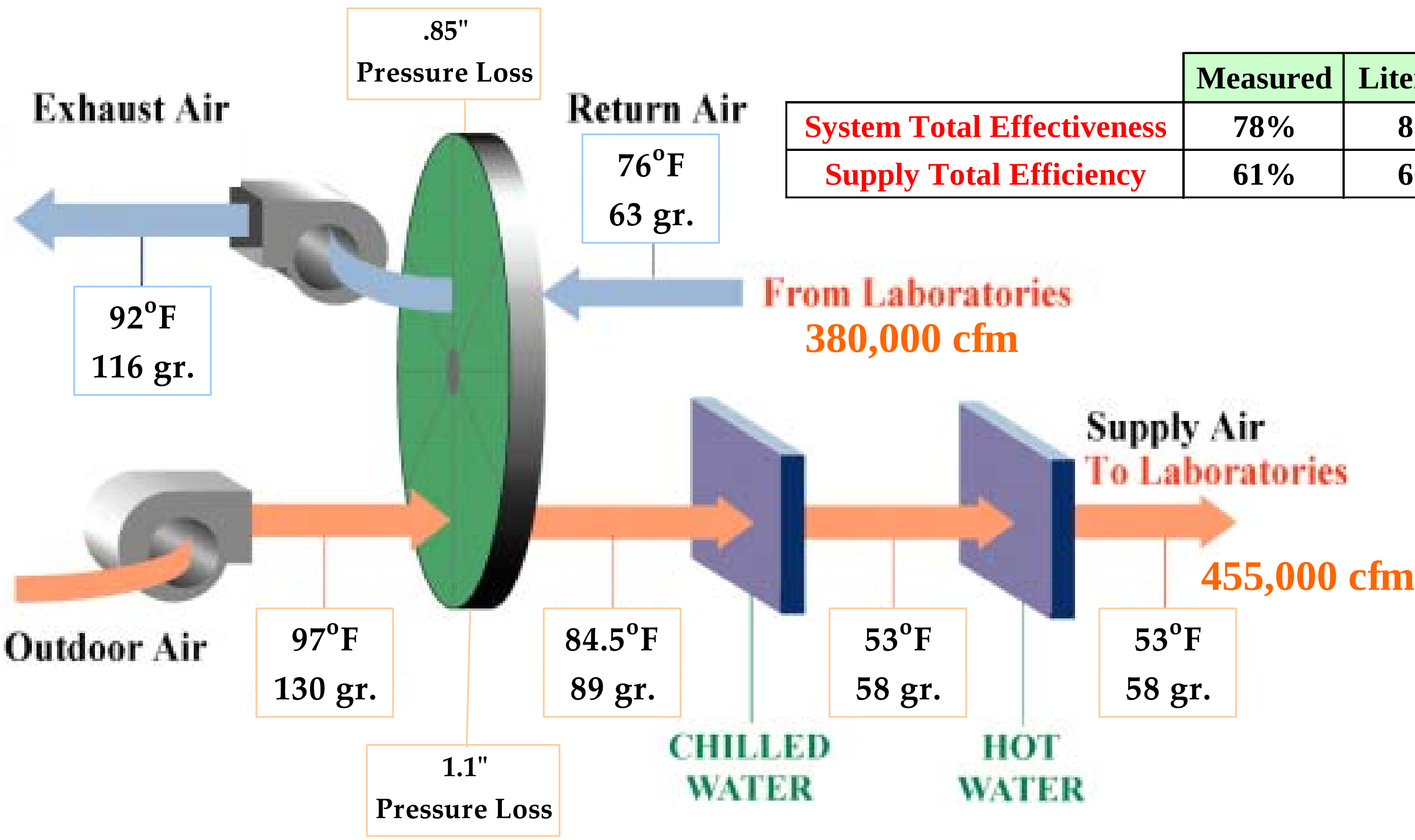
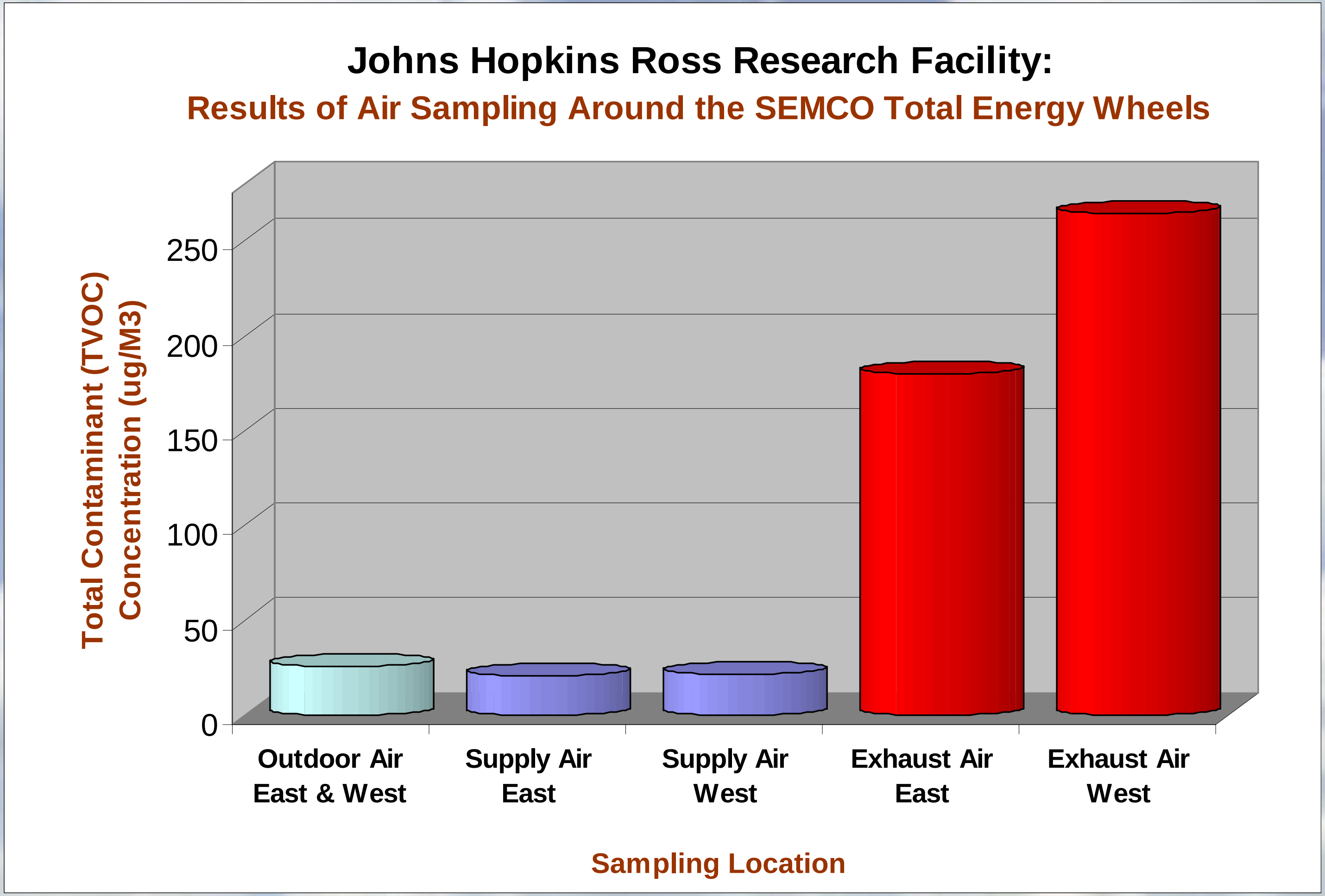
Actual Performance After 13 Years



	Measured	Literature
System Total Effectiveness	78%	80%
Supply Total Efficiency	61%	66%

Note actual trended data and field measurements: July 6th 2003 reflecting current airflow capacities
Note airflows shown reflect actual field measurements collected May 13th 2003

Cross-contamination Test Results



Actual field samples collected May 13th 2003 and analyzed via mass spectrometer by GTRI

Johns Hopkins Ross Research Building:
Recovery Wheel Risk Assessment

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Potential Sources for Carry-over of Airborne Contaminants

1) Energy wheel desiccant carry-over
2) Purge inefficiency
3) Seal leakage from dirty to clean airstream
4) Short circuiting between exhaust air outlet to fresh air inlet (system not wheel related)

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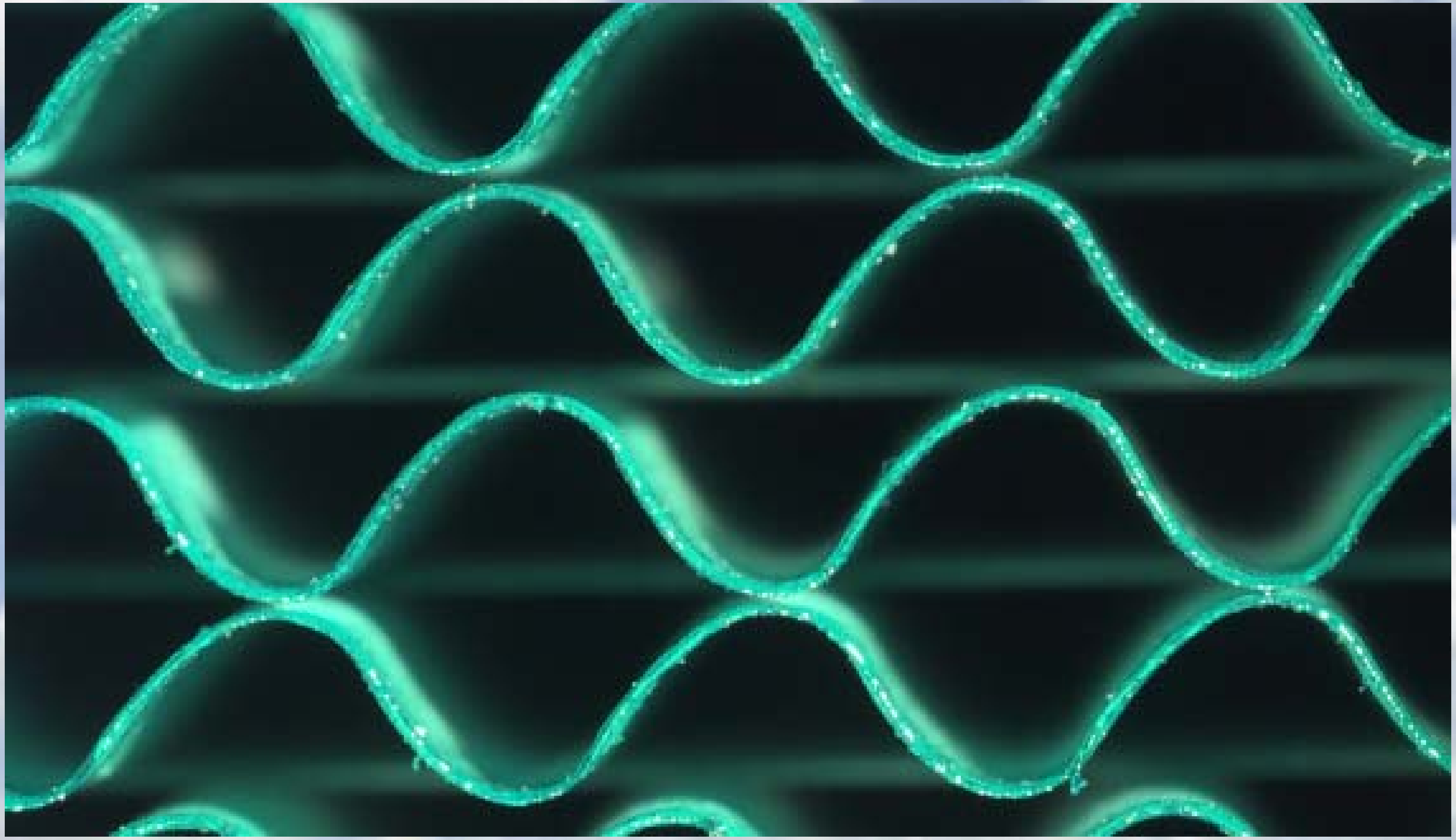
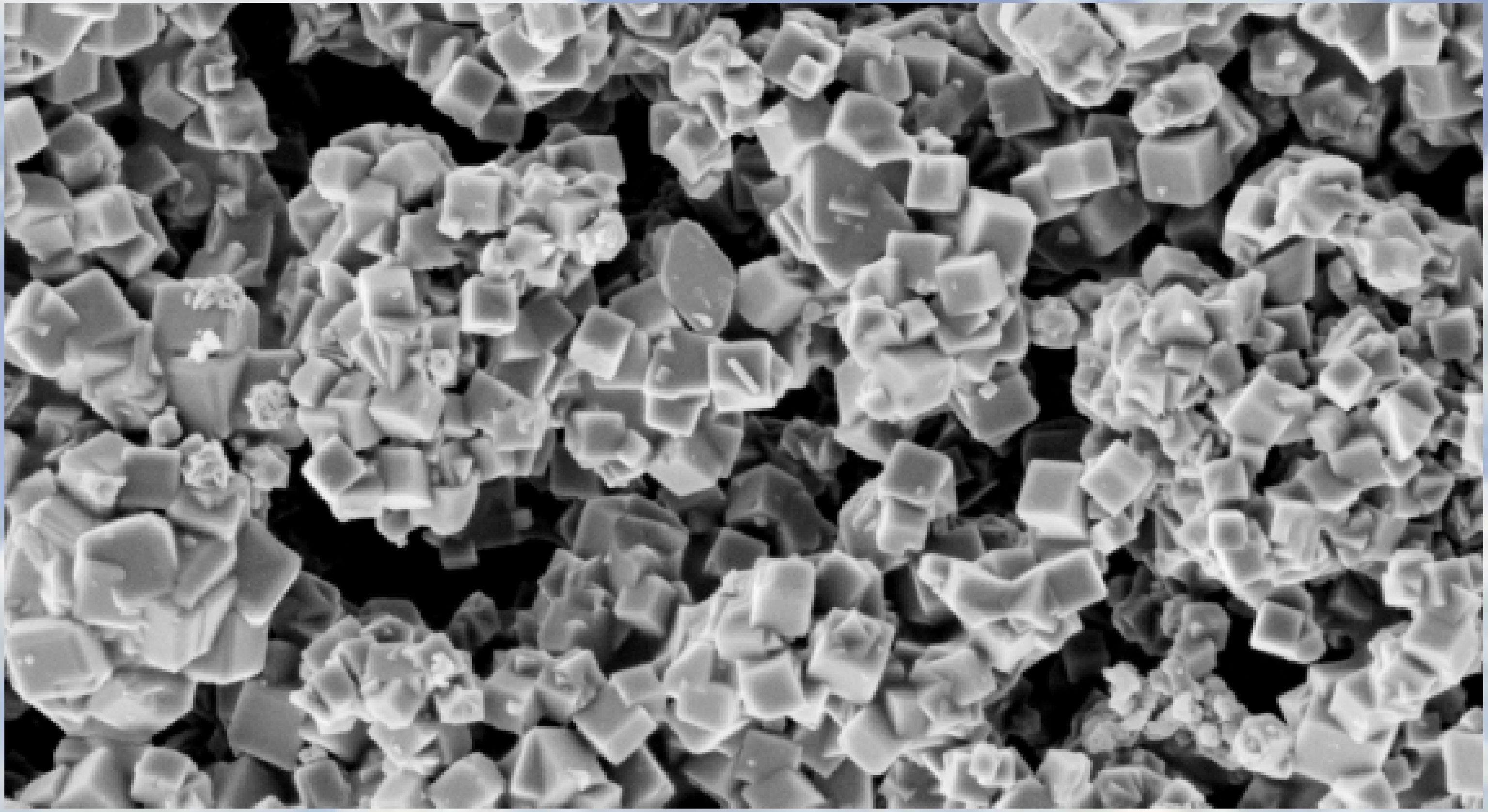
SEMCO Fluted Media: Face Coating



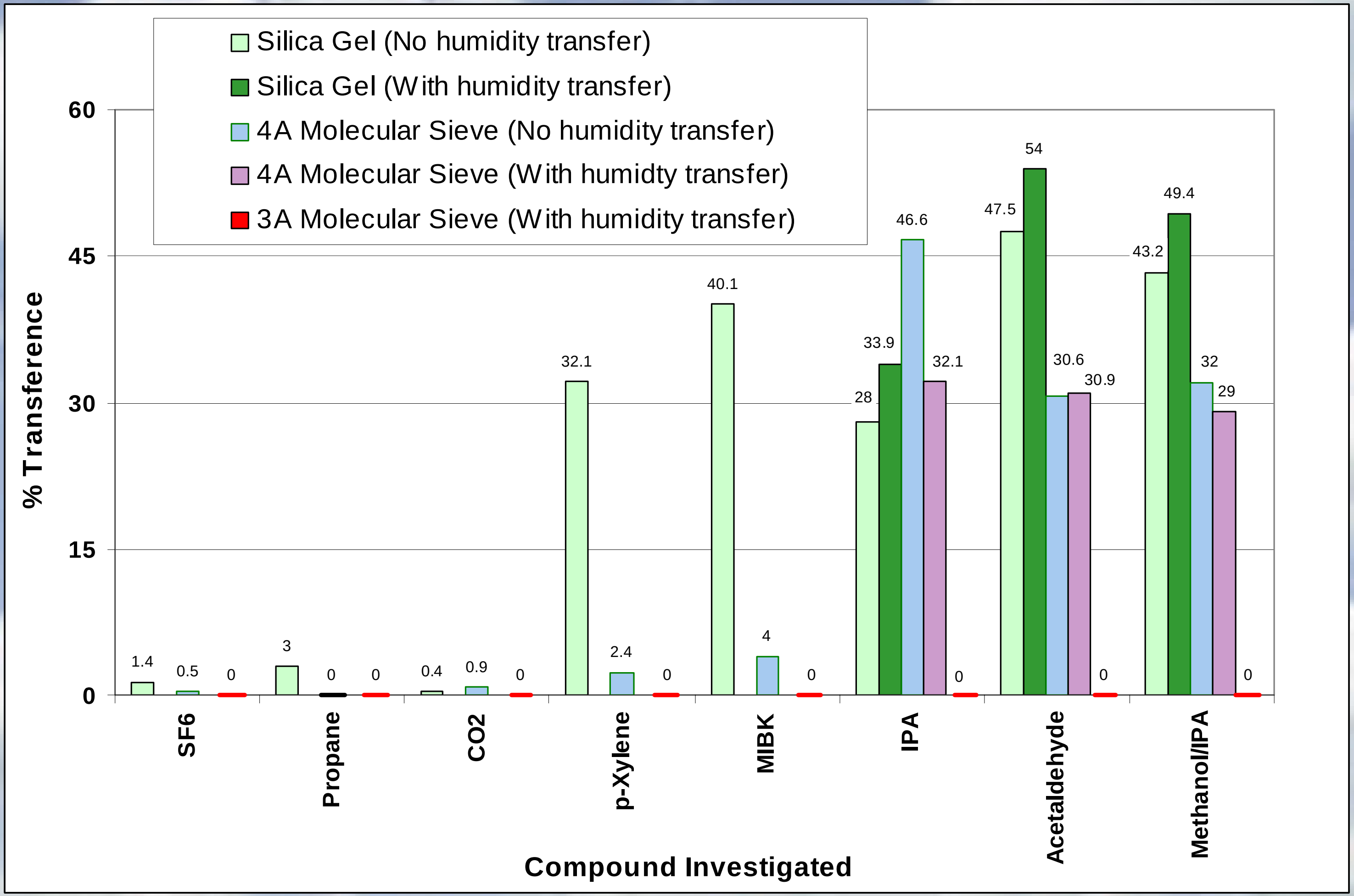
3Å Angstrom Molecular Sieve Desiccant Coating (SEM 10,000 X)



GTRI Pollutant Carry-over Research

- Desiccant materials other than a 3Å molecular sieve have been shown to transfer up to 50% of the airborne pollutants back to the space
- The 3Å molecular sieve coating was found to limit contaminant carry-over in the lab as well as in numerous field studies

Importance of the 3Å Molecular Sieve



Source: Independent Georgia Tech Research Institute Investigation 1993, 1999

Function of the Purge Section

- Purge dirty air trapped in wheel media as it rotates from the dirty to the clean airstream
- Purge angle adjustable and driven by the pressure differential existing between the outdoor air and return air streams
- Proper setting shown to limit carry-over to well below .045% in actual field commissioning tests

Bacteria and Virus Carry-over

- Organisms are not transferred by 3A molecular sieve, they are too large for the 3 angstrom pore (smallest virus is .3 microns or 3,000 angstroms)
- Particles have been shown to behave like gases and are limited to less than .045% of the exhaust air concentration based on lab and field testing
- Particulate can be easily filtered out, further reducing carry-over with 95.9995% efficiency (National Cancer Institute Investigation)

Risk Assessment Questions

- Should all lab hood exhaust be handled through the wheels? Some hood exhaust?
- Can the hoods be safely exhausted to the outdoors?
- If biological, HEPA filtration of supply and return air can drop carry-over limit from <.045% to <.000005%
- Safety benefit of constant volume system vs. variable flow system and complex controls

Assessment Procedure

- Assume worst case spill scenario for facility
- Evaluate chemicals used against resultant TLV levels using the .045% carry-over specification
- Evaluate for health risk and nuisance odors using % TLV and odor threshold values
- Determine which chemicals should be designated to separate hoods
- Choose appropriate system design, for example all exhaust through the wheels or just general exhaust

SEMCO Risk Assessment Database:

			AEI "Worst Case" Spill Scenario[3]		
Chemical Compound	**Total Quantity[1]**	**TLV NIOSH[2]**	**Supply Air Concentration**	**% of TLV**	**Comments**
ACETIC ACID BAR PVC CS6 500ML Total	171 liters	10 PPM	0.05 PPM	0.50%	Odor detection level 2 PPM
ACETIC ACID,REAG PVC CS-6X2.5L Total	8 liters	10 PPM	0.05 PPM	0.50%	"
ACETONE ACS REAGENT 20L Total	580 liters	750 PPM	0.05 PPM	0.01%	Odor detection level 2 PPM
ACETONE GR ACS 1L Total	508 liters	750 PPM	0.05 PPM	0.01%	"
ACETONE, 10L CS/2X10L Total	1100 liters	750 PPM	0.05 PPM	0.01%	"
ACETONE,ACS,REAG CS-4X4L Total	32 liters	750 PPM	0.05 PPM	0.01%	"
ACETONE-D6 (D,99.9%) 10G Total	1920 grams	750 PPM	0.05 PPM	0.01%	"
ACETONITRILE ACS REAGENT 500ML Total	109 liters	40 PPM	0.05 PPM	0.12%	Odor detection level 170 PPM
ACETONITRILE D3, 10GM Total	920 grams	40 PPM	0.05 PPM	0.12%	"
ACETONITRILE REAGENT 500ML Total	16 liters	40 PPM	0.05 PPM	0.12%	"
ACETONITRILE UV 4L Total	3980 liters	40 PPM	0.05 PPM	0.12%	"
ACETONITRILE UV, CS/2X10L Total	3600 liters	40 PPM	0.05 PPM	0.12%	"
ACRYLAMIDE BIS 29:1, 40% 500ML Total	4 liters	0.2 PPM	0.05 PPM	**25%**	No odor problem
AMMON HYDROX ACS PVC CS6 500ML Total	243 liters	25 PPM	0.05 PPM	0.20%	Odor detection level .04 PPM
BORIC ACID, UPR BIO-REA 500G Total	1 grams	N/A*	0.00 PPM	0.00%	
CHLOROFORM,ACS,REAG CS-4X4L Total	9 liters	10 PPM	0.05 PPM	0.50%	Odor detection level 190 PPM
CHLOROFORM,ACS,REGT 500ML Total	12 liters	10 PPM	0.05 PPM	0.50%	"
CHLOROFORM,REAG SS 500ML Total	16 liters	10 PPM	0.05 PPM	0.50%	"
CHLOROFORM-D (D,99.8%) 50GM Total	16750 grams	10 PPM	0.05 PPM	0.50%	"
DEUTERIUMOXIDE-D2(D,99.9%)100G Total	9200 grams	N/A*			No odor or health problem
DICHLOROMETH W/CYCLOHEX 4L Total	2724 liters	50 PPM	0.05 PPM	0.10%	Odor detection level 100 PPM
DICHLOROMETHANE ACS REAGE 1L Total	511 liters	50 PPM	0.05 PPM	0.10%	"
DICHLOROMETHANE HR-GC 4L Total	16 liters	50 PPM	0.05 PPM	0.10%	"
DIMETHYL SULFOXIDE AR 500ML Total	68 liters	High	0.05 PPM	<.10%	No odor, naturally occurring
DIMETHYLFORMAMIDE 1L Total	6 liters	10 PPM	0.05 PPM	0.50%	Odor detection level 100 PPM
DIMETHYLFORMAMIDE 100ML Total	11 liters	10 PPM	0.05 PPM	0.50%	"
DMSO-D6 10GSRM BTL-RUB SEPTUM Total	4290 grams	N/A*	0.00 PPM	0.00%	
ETHER ETHYL ANHYD AR 500G Total	569 liters	400 PPM	0.05 PPM	0.01%	Odor detection level 1 PPM
ETHYL ACETATE 4L Total	2840 liters	400 PPM	0.05 PPM	0.01%	Odor detection level 7 PPM
ETHYL ACETATE AR SAFE CN-1L Total	5 liters	400 PPM	0.05 PPM	0.01%	"
ETHYL ACETATE GR ACS 1L Total	1231 liters	400 PPM	0.05 PPM	0.01%	"

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Laboratory Systems Should be Commissioned with Tracer Gas

Project Tested by GTRI	Tracer Gas Test Data	
	Exhaust Air Recirculation to Outdoor Air Intake	Carry-over Total Energy Wheel
University Research Laboratory	0.14%	<.015%
Pharmaceutical Laboratory	0.10%	<.01%
Industrial Laboratory	0.08%	<.01%
Analysis Laboratory	0.11%	<.01%

Note 1: Sulfur Hexaflouride testing shown above completed by the Georgia Tech Research Institute Environmental Monitoring Branch under contract by SEMCO or the facility owner

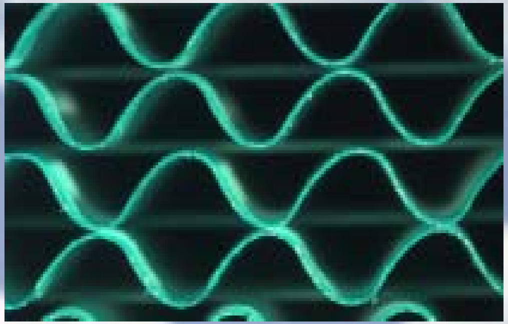
Note 2: Carry over is defined as the percentage of exhaust air concentration by volume. For example, .01% of 50 parts per million is .005 parts per million or 5 parts per billion

Separating Hood Exhaust from General Exhaust

- Some laboratory projects may involve research that will not tolerate even <.045% carry-over
- Excellent results still obtained with only 50% of outdoor air volume returned to wheels
- Due to high sensible internal loads in most labs, wheels have excess heating season capacity
- Significant chiller/boiler capacity reductions, energy savings and humidity control benefits still exist
- Offers a more conservative approach to lab designs

Labs for the 21st Century





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